LUBRICATION

A Technical Publication Devoted to the Selection and Use of Lubricants

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Diesel Tractor Lubrication

IT has been difficult for allied industries to keep up with the pace set by Diesel tractor manufacturers whose sales during the past few years, according to "Diesel Power," have totaled:

DIESEL TRACTOR HORSE-POWER

Prior to 1935	160,000
1935	460,000
1936	840,000
1937	1,100,000
TOTAL	2,560,000

The oil companies, however, have kept abreast of this rapid development, first, by intensive research determining, with the co-operation of the tractor manufacturers, the proper fuels and lubricants required; and, second, by making these products generally available even in isolated sections of the country.

ENGINE CONSTRUCTION

The Diesel tractor, built in sizes developing from 20 to 100 draw-bar horse-power, is very definitely invading the heavy-duty agricultural and industrial tractor field, principally because of its low fuel consumption. The engines are 4-cycle, solid injection Diesels having from 3 to 6 vertical cylinders and operating around 1,000 r.p.m., which, incidentally, is a rather economical speed for this type of engine. The combustion chambers are usually of the pre-combustion type and the exhaust is generally clean. The Diesel engine depends on high compression pressures to raise the air temperature above the self-ignition temperature of the fuel. To withstand these higher pressures, the engine construction is more rugged than in a corresponding gasoline engine, more piston rings are required and special bearing metals of high load carrying capacity are frequently used. Cylinder liners are usually removable and the trend seems to be towards the dry type. Lubrication is by the conventional force-feed system. Crankcase capacities are large to obtain low oil temperatures and permit settling of dirt. In short, the engines are built to give satisfactory performance in a very difficult type of service.

IMPORTANCE OF LUBRICATION

"Performance" to the Diesel tractor operator is a large word covering much ground. Good performance means plenty of power whenever needed and at a low cost; in other words, efficiency, reliability, good fuel and lubricant economy and low maintenance. Design is about half the battle in getting top-notch performance; the other half is the proper use of good fuels and lubricants.

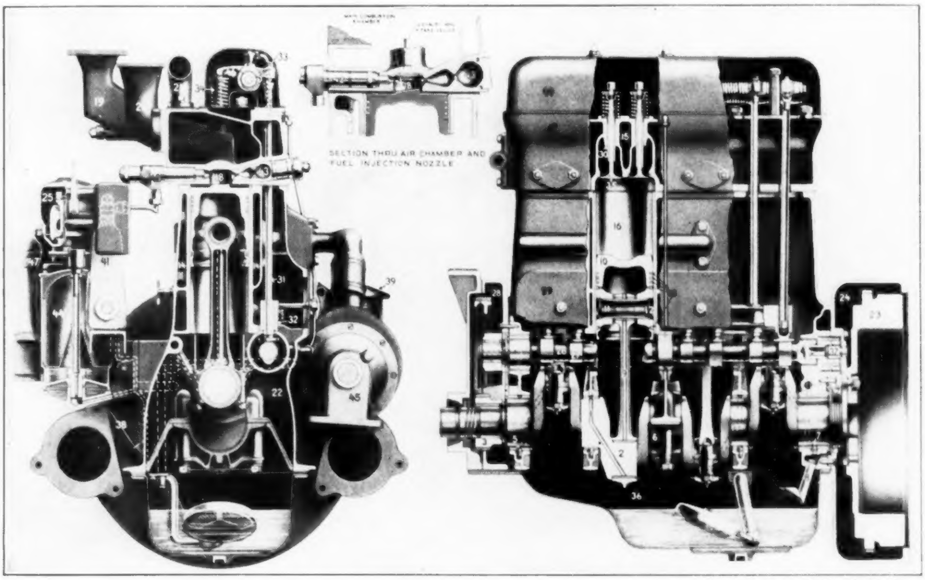
"Lubrication" is another big word in the tractor operator's vocabulary; in fact, good lubrication practically insures good performance since it not only has a lot to do with keeping the tractor on the job and out of the repair shop but, also aids in starting; and, combined with a good fuel, insures the greatest power output.

To illustrate its importance, let us compare the lubrication of a tractor with that of your own car. Instead of having the crankcase oil drained, perhaps, once a month, the oil in the tractor is frequently changed every other day,

and the tractor crankcase holds not six quarts but four gallons. You have the transmission and differential lubricants in your car changed twice a year, whereas the tractor's are changed sometimes every three weeks. Again, it's not 2 quarts but 10 gallons.

Your car is greased every month or two, if you are wise, by an expert with an air-powered grease gun, whereas the tractor operator gets down in the mud or dust every eight hours with a hand-operated pressure gun, forcing out all the dirt-filled grease and completely renewing the lubricants. If you fail to lubricate your car properly, it may be a year before you are suddenly faced with an expensive overhaul or a reduced trade-in allowance, letting the next owner pay the repair bill. The tractor operator has learned, however, that failure to lubricate his tractor properly shows up immediately in the form of reduced power, shut-downs for repairs, and high fuel and lubricant consumption. You may neglect your car and get away with it, but the tractor user must, and does, take care of his equipment.

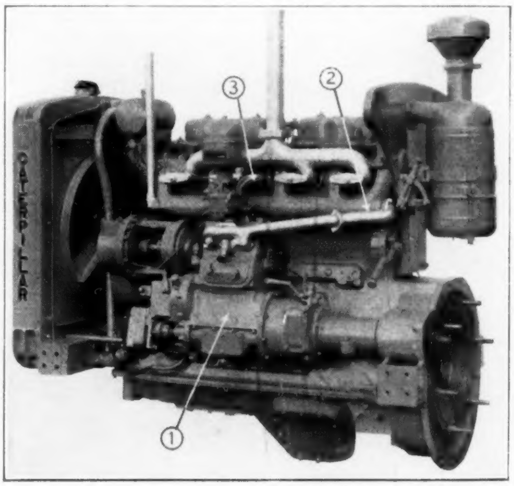
The tractor has presented several problems to the petroleum industry and, consequently, much has been spent in research and the development of suitable products to keep the tractors rolling. Since the average Diesel tractor uses annually about 5,000 gallons of fuel and 500 gallons of lubricants, and, since differences in design and service conditions necessitates different types of lubricants, it is but good common sense to rely on an oil company having a wide range of products and a staff of lubrication engineers trained in the fine points of tractor lubrication.



Courtesy of The Buda Co.

Fig. 1—Diesel with air cell in combustion chamber.

There are several things an oil gets in tractor service that it could very well do without. Since the chief job of the tractor is either plowing, scraping, shoving, pulling or otherwise moving dirt, the tractor is frequently operating either in a cloud of dust or a sea of mud; and, abrasive dirt, the arch enemy of lubrication, is continually working past the defenses erected by the designer. Even the best lubricant can



Courtesy of Caterpillar Tractor Co.

Fig. 2—Diesel utilizing separate gasoline engine for starting. Before starting engine (1) is engaged, Diesel is first warmed by starting engine cooling liquid at (2) and exhaust at (3).

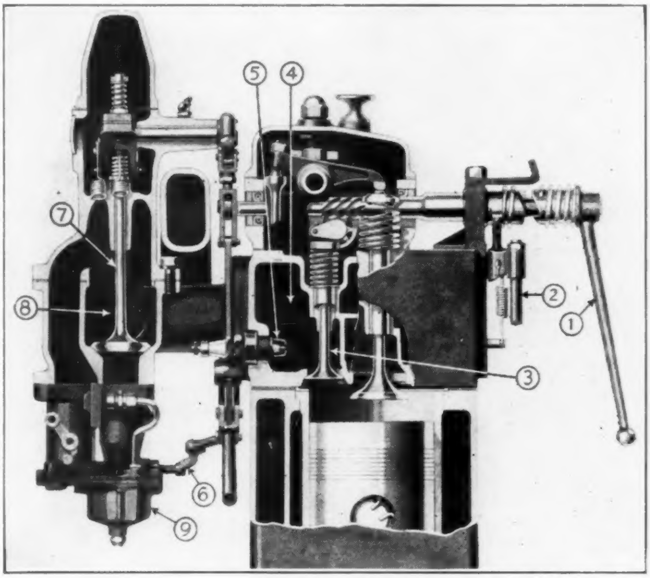
not fight dirt and, when contaminated, must be renewed.

The Diesel engine is fundamentally more difficult to lubricate than the gasoline motor because of basic design differences. Since Diesel fuel is more difficult to burn than gasoline, and, because it is given less chance to mix with the air required for combustion, on occasions a small amount of the fuel is only partially burned and this unburned fuel passes by the rings in the form of soot which cause ring sticking and sludge.

The higher pressures of the Diesel result in more blow-by of hot gases past the rings, burning the lubricating oil film. Also, certain types of oils don't get along very well with the special bearing metals used to handle these higher pressures. Suppose we examine the lubrication requirements of the Diesel engine a little more closely.

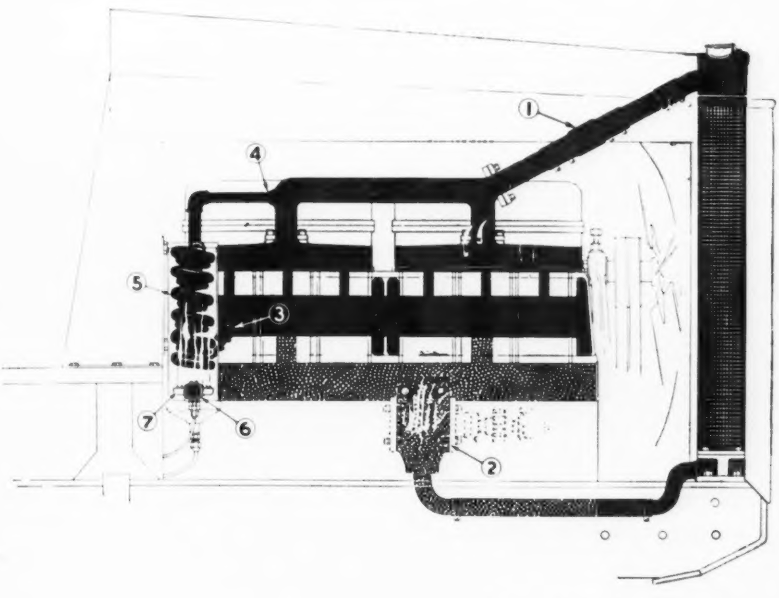
Engine Starting

The Diesel starting equipment must be able to turn the engine over against a high compression pressure of perhaps 500 pounds at a speed sufficient to overcome heat losses and raise the temperature of the air in the cylinder to the self-ignition temperature of the fuel. This starting temperature is difficult to attain by ordinary methods when the atmospheric temperature is below 32 degrees Fahr.



Courtesy of International Harvester Co.

Fig. 4—Engine is designed for gasoline starting. The engine is switched to gasoline starting by turning crank (1). This opens valves (3) to the auxiliary combustion chambers (4). Spark plugs (5) are located in the auxiliary chambers. Crank (1) also closes butterfly valve (6) shutting off direct air inlet and opens valve (7) permitting intake manifold (8) to contact gasoline carburetor (9). A high tension magneto supplying current to the spark plugs is also engaged. After the engine has made a pre-determined number of revolutions, rod (2) releases the shaft turned by lever (1) automatically changing the engine to Diesel operation.



Courtesy of The Cleveland Tractor Co.

Fig. 3—Engine is equipped with water heater to warm Diesel before starting in cold weather. (1) Thermostat; (2) Water Pump; (3) Inlet to Water Heater; (4) Hot water outlet from heater to engine; (5) Heater coils; (6) Heater control valve; (7) Burner.

Interesting methods are employed to assist in starting at low temperatures. One manufacturer designs his Diesel engines to start on gasoline by decreasing the compression and using gasoline mixture with spark plug ignition. This permits the engine to be cranked by hand. After the engine operates a predetermined number of revolutions it is changed automatically into Diesel operation.

Another Diesel tractor is equipped with an auxiliary gasoline starting engine whose cooling system is inter-connected with that of the Diesel. The gasoline engine is first started

and allowed to run independently until its exhaust gases and cooling water have warmed up the Diesel sufficiently to permit easy starting.

A third Diesel tractor is warmed before starting by means of a gasoline burner built in the cylinder block.

Courtesy of The Cleveland Tractor Co.

Fig. 5—Application of blow torch to cooling liquid heater to warm engine prior to starting in cold weather.

Other aids to starting are: compression release devices which hold the exhaust valves open until the engine is rotating at a sufficiently high speed to permit starting; electrically heated elements or glow plugs; intake air heaters and hand primers which permit spraying into the intake manifold of ether, kerosine or other special fuels having a low ignition temperature.

Cold weather starting is sometimes an important consideration affecting the choice of crankcase oil body or viscosity. Two requirements must be met by a lubricant to permit easy starting. First, the pour point must be below the temperature of the oil when the starting attempt is made. Second, the viscosity of the oil should not be over 20,000 seconds at the oil temperature. Fortunately, the practice of heating the engine by various means before trying to turn it over with the starter sufficiently elevates the oil temperature so that the oil which has the best operating characteristics can be selected without regard to its starting ability. This is of considerable importance, otherwise oils which are least viscous at low temperatures would have to be used, and unfortunately they are often least effective in preventing ring sticking.

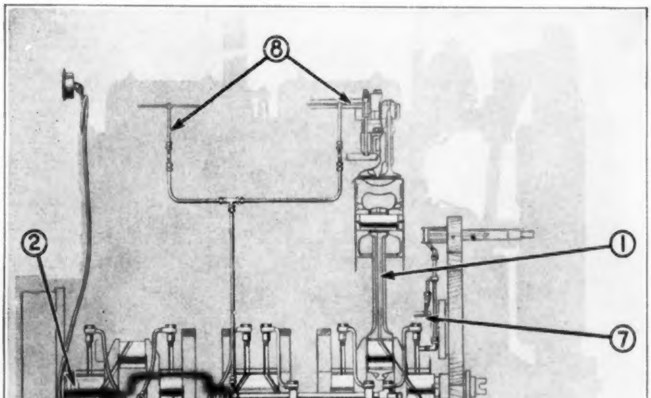
Wear

Until recently, it was commonly believed that heavy oils, SAE 50 and SAE 60, were necessary to provide a sufficiently thick oil film to prevent wear under the dust conditions in which the tractor must operate. It has been found, however, that the heavier oils are not necessary and now SAE 10 and SAE 20 oils are frequently recommended. The use of light-bodied oils has several advantages, particularly those which are relatively thin at the higher temperatures. The principal advantages are less ring sticking difficulties, which reduce maintenance costs, and less drag or friction, thus improving fuel economy.

Engine Oil Consumption

The amount of oil consumed by the engine depends principally upon the amount of oil splashed to the cylinder walls and the degree of oil control offered by piston rings. The quantity splashed is influenced by oil pressure and bearing clearances, while the effectiveness of the piston rings depends, among other things, on the use of an oil which keeps the rings free and clear.

The viscosity or body of the oil does affect consumption, however, the thinner oil causes less drag on the moving parts and numerous tests have shown that the increased consumption of a lighter oil is practically balanced by a corresponding reduction in fuel consumption.



Courtesy of Caterpillar Tractor Co.

Fig. 6—Full pressure lubrication system. (1) Connecting rods drilled for pressure lubrication to piston pins. (2) Spiral groove for carrying oil back away from clutch. (3) Auxiliary oil pump to bring oil from forward sump. (4) Main pressure oil pump at lowest part of engine assembly. (5) Drilled holes in crankshaft carry oil under pressure to all crank pin bearings. (6) Auxiliary pump suction bell to return oil to main sump. (7) Camshaft bearing lubricated under pressure. (8) Oil line to valve rocker arm shafts and push rod cups assuring continuous lubrication.

Therefore, the fact that oils thin out at higher temperatures is of no economic importance, provided the oil remains sufficiently viscous to prevent contact between the rings and the cylinder walls. Since careful tests have demon-

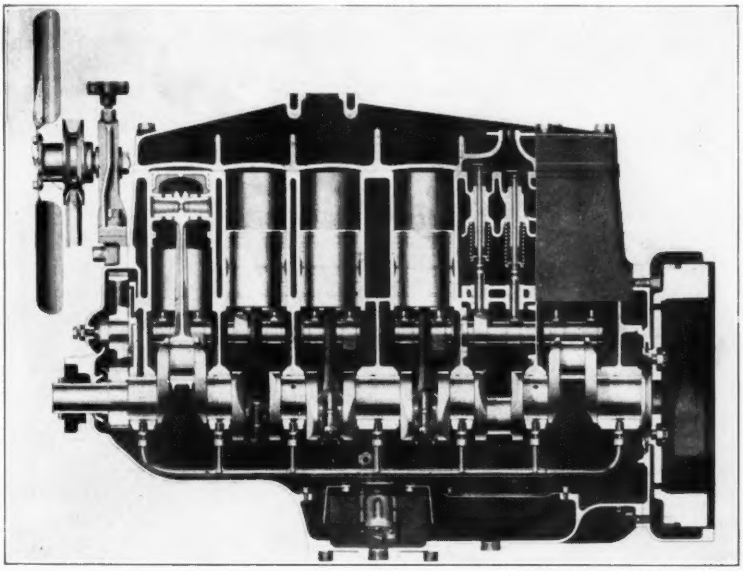
strated that up to 75 per cent kerosine can be added to an oil before cylinder wear is appreciably affected, the use of light oils is clearly sound practice.

The further reduction of oil consumption by close clearances and the adoption of oil coolers is permitting the use of the lighter oils, which are more desirable lubricants from other standpoints.

Any appreciable increase in oil consumption is a rather positive indication that something is mechanically wrong, and this condition should be corrected rather than resorting to the use of heavier oils; otherwise, the mechanical defect may develop into serious and expensive difficulties.

High-oil consumption usually indicates that bearing clearances have become excessive so that too much oil reaches the cylinder walls, or that rings are in poor condition, allowing too much oil to pass by.

Abnormally, high-oil consumption may result from thinning of the lubricant by fuel dilution, from overheating of the engine, from oil leakage, and from many other factors; an important one being the use of an improper type of oil.

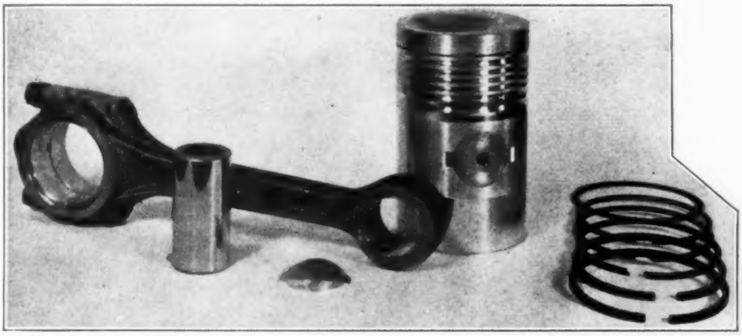


Courtesy of Hercules Motor Corp.

Fig. 7—Full pressure lubrication system. Note oil seal preventing leakage at flywheel.

ENGINE BEARINGS

Babbitt, cadmium-silver, and copper-lead are the metals commonly used for main and connecting rod bearings. The Babbitt may run as high as 90 per cent tin; the cadmium-silver will contain nearly 98 per cent cadmium; and the copper-lead bearing may consist of as much as 75 per cent copper. Since tin is not a natural resource of the United States, the use of other metals as bearing materials, although occasioned by their greater load-carrying ability, may some day indeed prove fortunate.



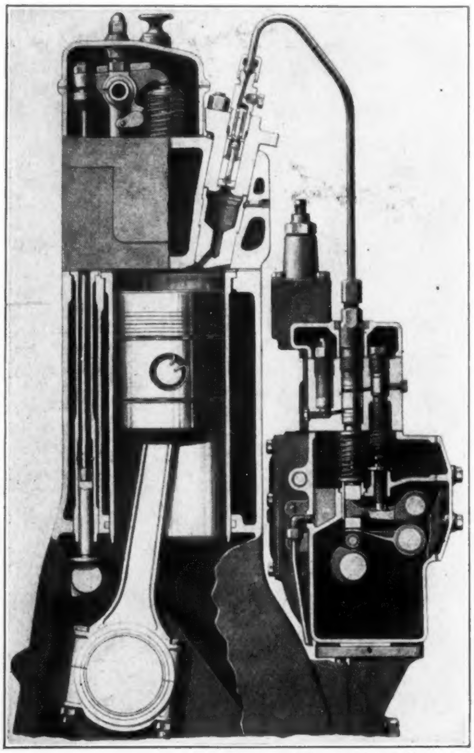
Courtesy of Caterpillar Tractor Co.

Fig. 8—Connecting rod and piston assembly. Two oil rings above pin, four compression rings and groove to reduce heat transfer to rings.

A bearing will withstand a certain maximum combination of bearing pressure and rubbing velocity. At higher temperatures, the bearing metals' strength is reduced and the allowable load-speed capacity is lowered.

The tractor operator is primarily interested in avoiding the operating conditions which result in bearing failure. Probably the greatest load is imposed when the tractor is first started each day. Under ordinary running conditions, only part of the total fuel charge is injected before ignition occurs and the initial shock resulting from the burning of the fuel present at the time of ignition is not excessive. Under starting conditions, the cylinder is comparatively cold, and all the fuel is injected before ignition occurs. Generally, several injections take place before ignition occurs, and the resultant explosion, when all this fuel burns instantaneously, transmits a tremendous shock to the bearings. Therefore, to prevent bearing failure, use a fuel which will ignite quickly, as indicated by a high cetane number. When

starting, don't open the throttle until the engine cylinders are thoroughly warmed either by heat of compression, as a result of motoring the engine with the starting unit, by such



Courtesy of International Harvester Co.
Fig. 9—Pre-combustion chamber type Diesel.

auxiliary means for heating the engine as the manufacturer has provided or by operating those tractors so equipped for a short interval on gasoline. Overspeeding is something else that the operator must avoid to get long life from the bearings. The maximum bearing pressure at high speeds is not due to the explosion pressure, but to the sudden reversal of motion of the piston at the top of its stroke. This sudden retardation, combined with the high-bearing surface velocity generated at high speed, will cause rapid wear of the lower halves of the connecting rod bearings. The engine governor will ordinarily prevent overspeeding, but, the operator must be careful in going down grade, particularly if pulling a heavy load.

All oils, when exposed to high temperatures in the presence of oxygen, will react and under severe conditions may be corrosive to certain combinations of sensitive metals. Babbitt appears least subject to corrosion while copper-lead and cadmium-silver are more easily attacked. Straight naphthenic oils rarely, if ever, cause corrosion, while compound oils are apt to be rather active chemically. In view of this situation, the tractor operator should consult competent lubrication authorities in selecting the oil for his tractor.

In passing, it should be pointed out that the present trend towards closer bearing clearances reduces the quantity of oil pumped through the bearings unless oil pressures are raised. This reduction in cooling effect results in higher bearing temperatures and increases the possibility of corrosion.

If, after selecting the proper lubricant, the operator drains the oil as recommended and maintains the proper oil level, he should not experience bearing difficulties.

SLUDGE IN ENGINE

In addition to products formed by chemical changes in the lubricating oil, other products such as, soot from the fuel, dirt, metal from excessive wear, rust, water, anti-freeze, and oil filter materials are among the substances which cause co-agulation of the oil into that highly undesirable condition generally described, for lack of definite knowledge, as sludge.

Our analysis of many samples of sludge shows that this frowned-upon material is, nine times out of ten, perfectly good oil mixed with soot from the fuel, and that, excessive blow-by is usually a contributing factor.

Over a gallon of water is formed as a result of the combustion of each gallon of fuel, and the blow-by gases consequently are heavily charged with steam. Thus, if the crankcase is cool or not well ventilated, some of the steam is condensed to water and this emulsifies the oil. This emulsion may be jelly-like or very tarry if mixed with sufficient carbon.

Sludge only occasionally results from oxidation of the oil. Since an oil, which resists oxidation, will generally form tarry products due to other types of chemical changes, laboratory oxidation tests have little service significance. The method of refinement influences chemical stability more than the type of crude. When oxygen atoms from the air join with the carbon and hydrogen atoms in the oil, new products are formed. First, there are formed aldehydes, peroxides, acids, etc., then anhydrides, other saponifiable bodies, resins, asphaltenes, carbenes and carboids, and if the oxidation is carried far enough, carbon is formed. Each of these materials is distinguished by its carbon-hydrogen ratio. The greater the oxidation, the greater the carbon to hydrogen ratio of the oxidation products. These products in the laboratory are identified by their solubility in organic solvents. By one definition, resins are those materials insoluble in propane but soluble in isopentane. Asphaltenes are insoluble in isopentane but are soluble

in carbon tetrachloride. Carbenes and carboids are insoluble in carbon tetrachloride. The formation of acids parallels the general oxidation process, so that the determination of the amount of acid formed is a rough indication of the amount of oxidation that has occurred. The oxidation products, with the exception of asphaltenes, carbenes, carboids and carbon, are largely soluble in the oil. Thus, to obtain 0.5 per cent in soluble sludge from oxidation alone, requires very severe oxidation such as seldom occurs in practice; for example, a laboratory oxidation test shows that a stable, well-refined oil must have a neutralization number of more than 3 and a viscosity increase at 210 degrees Fahr. of 6 to 7 S.S.U. This same oil when run in an engine under very severe conditions showed a neutralization number of 4.58 dissolved sludge of 3.86 per cent and *undissolved* sludge of only 0.38 per cent, thus indicating that extensive oxidation had occurred but practically all of the oxidation products were soluble in the oil. Engine deposits to be termed as such must necessarily be insoluble in the oil. Therefore, other factors than oil oxidation alone are necessary to give appreciable engine deposits.

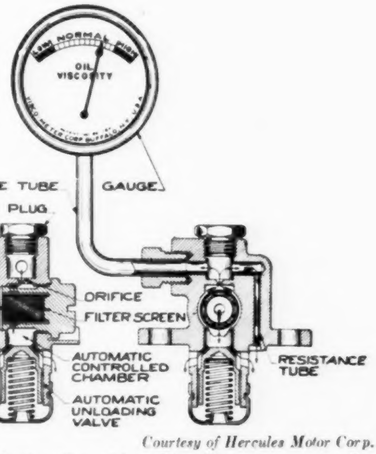
Crankcase sediment is undesirable for many reasons. Oil lines or screens may clog, causing bearing failure or piston seizure. Sludge, coating the inside of the crankcase, acts as insulation and raises the oil temperature which, in turn, induces oxidation of the oil. Solids in the lubricating oil also contribute to ring sticking and clog oil ring holes, thus increasing oil consumption. Sediment may hold the oil relief valve open, causing a drop in oil pressure. Water in the crankcase not only interferes with lubrication and causes rust but may freeze in cold weather at the oil pump, preventing the flow of oil, and even may cause pump breakage. For these reasons and also because the sediment may contain dirt, iron or other abrasive or corrosive substances, any sludge formation in an engine should be removed, the crankcase thoroughly cleaned, and an examination made to determine the mechanical condition causing the deposits.

The Diesel manufacturer has greatly lessened, the sludging tendency of the engine by providing clean combustion and well-fitted piston rings. He has learned how to design and machine pistons, rings and cylinders so that there is a good seal between the combustion chamber and the crankcase when the engine is at the proper operating temperature. If the operator allows the engine to operate at low-jacket temperatures, not only will combustion be less complete, but clearances will be greater, thus providing a combination of conditions which will permit contamination of the lubricating oil with fuel soot. Advances in metallurgy permit the designer to select piston ring and cylinder metals of the proper hardness and grain structure which maintain an effective fit for long periods of time. The wearing surfaces are carefully conditioned by the use of special break-in oil or by various means such as "Sulphonation," "Ferrox Surfacing," tin plating or other methods. All this care is wasted, however, if the engine is not kept free from dirt. This is not difficult if the instructions for taking care of the air cleaners are carefully followed and the crankcase oil is changed as recommended.

Piston rings must be kept free and should be cleaned or replaced when necessary; otherwise, the resultant blow-by will cause sludge formation either from fuel soot, water or burning of the oil by the hot blow-by gases.

Blow-by in an engine is not difficult to detect since it will usually be accompanied by a loss in power, increased oil consumption, and smoke at the crankcase breather.

Regardless of the condition of the engine, a



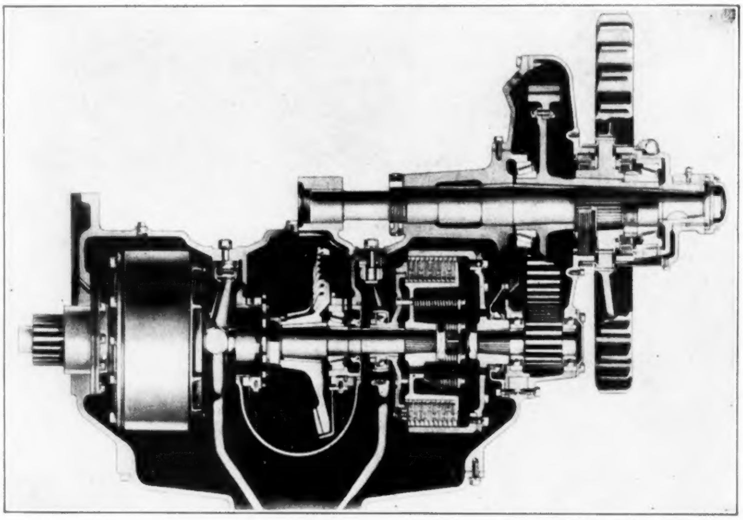
Courtesy of Hercules Motor Corp.

Fig. 10—One Diesel engine with a Visco-Meter instrument that indicates the viscosity of the oil just before entering the main bearings. The Visco-Meter action is as follows: Some of the lubricating oil is lead from the main oil header in the engine through a short insulated copper tube shown as "oil supply" to the instrument. It enters the instrument through an orifice into a filter screen. It passes through the screen into an "automatic controlled chamber" which has an orifice on one side and a spring loaded check valve called an "automatic unloading valve" at the other. The oil may enter the instrument at any pressure but this check valve is permanently set at a pressure low enough so the oil in the chamber is under a constant even pressure regardless of engine pressure unless the engine pressure becomes less than the setting of the unloading spring. The excess oil flows past the check valve and spills back into the engine crankcase. The rest of the oil passes through the orifice on the other side of this chamber which connects with the resistance tube. The other end of the resistance tube connects with the engine crankcase so some of the oil passes through this resistance tube and spills into the engine crankcase. This resistance tube is purposely restricted in size to restrict the flow of oil through it and thereby set up a pressure in the gauge tube line. Part of the oil therefore is under a pressure determined by the rate of flow of oil through the resistance tube and this is registered on the gauge dial by the indicator hand.

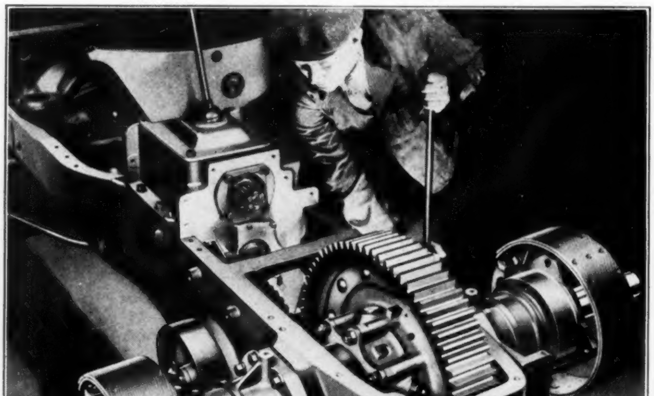
As thick oil will not flow as rapidly through the resistance tube as thin oil under the same pressure, the indicator hand registers higher with the thick oil as the pressure in the gauge line is higher. The thinner the oil the less the pressure in the gauge line as there is less resistance to the flow through the resistance tube, and the lower the gauge reading.

certain amount of blow-by gases containing steam will get past the rings and the hot crankcase air will absorb large quantities of moisture. This steam will condense in the engine if the crankcase temperature is much below 130 degrees Fahr. In very cold weather, it may be impossible to keep the crankcase hot, and the oil must be drained frequently to remove the water which will inevitably condense. The engine is usually equipped with a thermostat in the water system to keep the crankcase above the condensation temperature. Frequently, in cold weather, especially when starting and when engine is idling, part of the radiator should be covered to prevent the formation of water in the crankcase.

There is usually a natural draft through the crankcase which continually renews the air, preventing it from reaching the saturation point. The crankcase breather is ordinarily placed in the oil-filler opening. To prevent the entrance of dust, this breather is equipped with an air filter. Many cases of sludge are due to failure of the operator to keep this air-cleaner clean and unobstructed. A clogged air-cleaner on the breather interferes with the proper ventilation of the crankcase, allowing the air within to become saturated with moisture, resulting in the condensation of water in cold weather. These precautions are of the greatest importance in humid climates.



Courtesy of Caterpillar Tractor Co.
Fig. 12—Final Drive—cross section. Note bellows type oil seal at sprocket.



Courtesy of International Harvester Co.
Fig. 11—Final Drive.

The operator can further insure against water in the crankcase by keeping all gaskets tight, particularly the seal where a wet type cylinder liner is used.

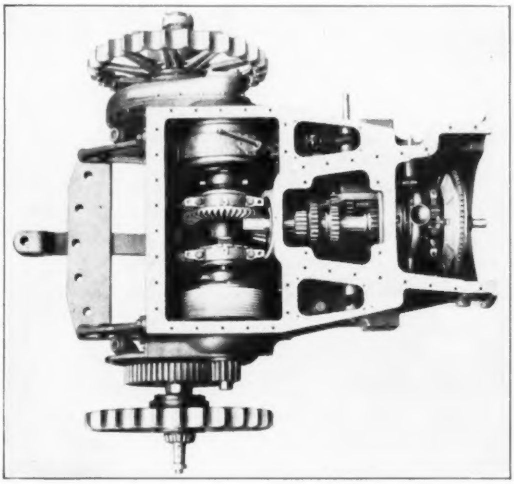
Not only must the crankcase be kept warm to prevent water emulsions, but also must not be overheated, or sludge, due to oxidation of the oil, will occur. The ideal temperature for tractor Diesel crankcase oil is probably between 150 and 180 degrees Fahr., although oil temperatures over 200 degrees are not uncommon.

RING STICKING IN ENGINE

While a satisfactory interpretation of the causes and cures for ring sticking has not as yet been advanced, most of the known facts will fit in well with the following explanation.

It is generally agreed that the lubricant, the fuel and the ring temperatures are important factors. All oils apparently have critical temperatures at which they form deposits. It has been pretty definitely established, after years of experience, that the temperatures in a Diesel are such that properly refined naphthenic oils

evaporate more cleanly and leave less deposit than other types of straight mineral oils. In fact, most slow-speed engines, and even high-speed engines in some types of service, have operated on naphthenic oils with no ring sticking difficulties. Some believe that the reason the larger, slow-speed engines have been relatively free from ring sticking, as compared to their younger, faster brothers, is the more complete burning of the fuel. It is obvious that at 900 r.p.m. it is going to be harder to get all the fuel burned than at 300 r.p.m.



Courtesy of Caterpillar Tractor Co.

Fig. 13—Transmission and top view of final drive shown in Fig. 12. Power transmitted from engine through clutch, transmission, pinion and bevel gears, steering clutch, reduction gears to track sprocket.

In the high-speed engines, then, the fuel probably contributes some of the carbonaceous material which causes ring sticking. Under full-load operation, due to some mechanical defect, such as sticking valves or poor spray action or simply because of the injection of more fuel than there is air to burn, part of the carbon will remain in the cylinder.

Some authorities believe that most of the deposits which cause ring sticking originate from chemical changes in the lubricating oil in several different ways:

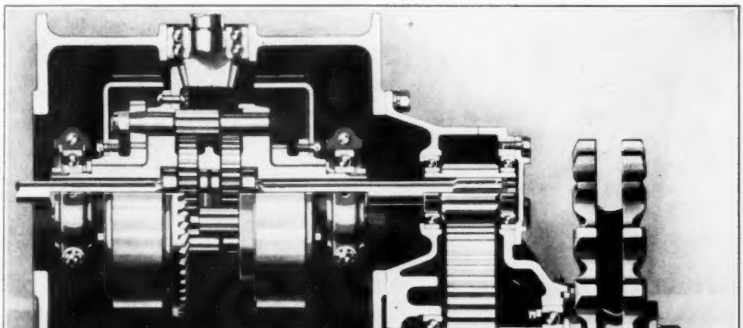
When oil is heated sufficiently, it volatilizes or boils away leaving behind a carbon residue.

At high temperatures the oil molecules join together, forming a heavier molecule which is a solid rather than a liquid.

As previously explained, oil is also subject to oxidation.

With the ring grooves becoming clogged with these fuel or lubricating oil deposits, the stage is set for the entrance of the recently introduced compounded oils. These oils are generally of the naphthenic type, which have proved so successful in slow-speed engines. Materials have been added which improve the original, excellent ability of naphthenic oils to keep rings free and clean. These oils may be said to have a solvent action on ring deposits, although, strictly speaking, the word "dispersion" probably should be used since the oil does not actually dissolve the carbonaceous solids but merely holds them in suspension in a finely divided state. This explains why these oils frequently turn black quickly and, yet, leave no crankcase deposits. It also explains why comparatively coarse filters stay clean while finer filters clog rapidly when the compounded oils are used.

The same additives which prevent ring sticking may also disperse carbonaceous material around the oil rings maintaining low oil consumption by preventing clogging of oil ring holes or slots. This dispersion action may also prevent the deposition of tarry material in the crankcase.

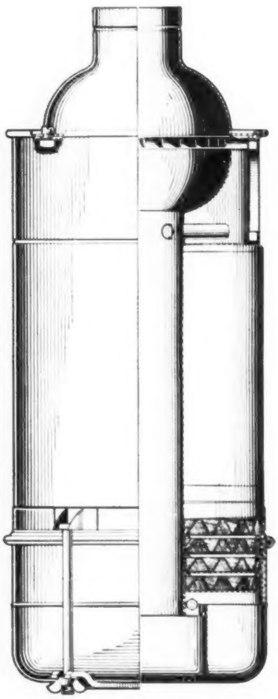


Courtesy of The Cleveland Tractor Co.

Fig. 14—Final Drive.

Metallic soaps are the principal additives used to improve ring sticking. Sulfur and oiliness agents used to impart certain other char-

acteristics to lubricants do not seem to improve ring sticking a great deal, and the success of oils containing them can generally be credited solely to the naphthenic oil used as a base, since the naphthenic oil itself usually reduces ring sticking materially:



Courtesy of International Harvester Co.
Fig. 15—Oil wash type air cleaners.

Certain precautions should be observed in the use of compounded oils in Diesel engines:

1. In many cases, the metallic soap used will cause corrosion of certain types of alloy bearings, so the compounded oils should only be used in engines equipped with Babbitt or other corrosion-resisting bearings, unless proved to be harmless.
2. The effectiveness of the compound will be reduced if the oil is not changed in accordance with the tractor manufacturer's recommendations; usually not over 60 hours between drains is suggested.
3. When changing to a compounded oil, the crankcase should be drained every 30 hours for the first 90 hours to remove former deposits loosened by the cleansing action of the compounded oil.
4. The effectiveness of the oil will be lessened if extra fine filters are used.
5. The compounded oils should not be used in air-cleaners as they have a tendency to foam.
6. The various compounds used to prevent ring sticking vary greatly in their sludging, corrosion and wear characteristics, so that all compounded oils should not be condemned because of the failure of one.

While the use of special lubricants has permitted certain engines to operate longer before ring sticking occurs, its prevention is principally a question of design and operation. The generally accepted practice is to reduce the top ring temperature as much as possible, since usually, but not always, the top ring is first to stick. Each Diesel designer seems to have a different solution to this problem. Some provide sufficient metal in the piston to furnish a path for the heat to flow to the lower part of the piston; others attempt to isolate the ring belt from the piston head and remove the heat by an oil spray under the piston head. It has been found that the selection of the proper piston and ring metal is important, as is the heat treatment and the shape and fit of the piston rings. The cooling effect of the fuel striking the piston and evaporating may possibly be responsible for comparative freedom from ring sticking in some direct injection engines.

Generally speaking, the engine builder has produced a unit which can be operated for reasonably long periods before overhaul, due to ring sticking, is necessary. The operator must, however, prevent his engine from being over heated or overloaded; the injection equipment must be given proper care and other precautions taken to insure complete combustion; and the proper types of fuel and lubricant must be used.

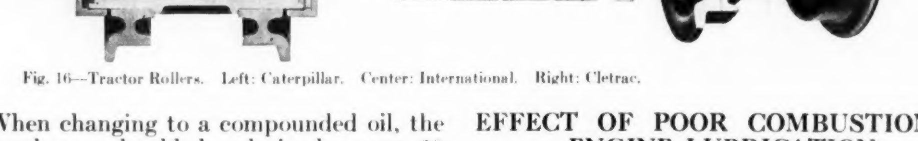


Fig. 16—Tractor Rollers. Left: Caterpillar. Center: International. Right: Cletrac.

EFFECT OF POOR COMBUSTION ON ENGINE LUBRICATION

Since fuel residues play an important part in sludge formation and ring sticking, the Diesel tractor should be operated and maintained in a manner which permits the fuel to burn as completely as possible, to insure good lubrica-

tion. Excessive smoke at the exhaust should not be tolerated. To prevent it, only fuels meeting the engine manufacturer's specifications should be used. The fuel must be kept clean; allowing the fuel to stand for 24 hours after delivery before use is reasonably safe insurance against dirty fuel reaching the engine. The fuel filter should be maintained in an efficient condition. Fuel containers must be thoroughly protected against the entrance of water and dust.

The spray nozzles should be kept in proper adjustment and the injection timing checked periodically.

Excessive idling should be avoided as the temperature in the cylinder may drop below the ignition temperature of the fuel, and either late burning or actual misfiring may occur. To insure ignition of the fuel, water temperatures should be kept above 160 degrees Fahr. and preferably around 190 degrees.

Injecting more fuel than the engine can burn is a common cause of incomplete combustion. The Diesel should not be overloaded by running it at loads and speed in excess of manufacturer's ratings. The air cleaner should be kept clean and only a light oil used in it to prevent restriction of the intake air. At high altitudes less fuel can be injected than at sea level, due to the decreased weight of air entering the engine. Engine valves should be kept free by the use of proper oil and by cleaning as necessary. If the valves stick open longer than intended, badly needed air will escape and combustion will be incomplete at full load.

Overheating Impairs Engine Lubrication

A hot running engine is a common cause of lubrication failure. Excessive oil temperatures result in ring sticking and sludge formation. All oils become less viscous or thinner at higher temperatures, and oil consumption increases.

The designer has usually provided the necessary water-cooling system capacity to maintain a reasonably low oil temperature. The use of oil coolers, which permit the use of lighter grades of oil, is noted in latest designs. To prevent overheating, it is merely necessary for the operator to take normal precautions to keep the radiator clean inside and out, the fan belt tight, the inside and outside of crankcase clean, and to use clean water in the cooling system. In addition, the crankcase should be kept full of oil and oil coolers should be cleaned periodically.

ENGINE OIL FILTERS AND OIL CHANGING

There is no question but that the use of the right type of oil filter improves lubrication, provided the filter is of sufficient capacity and is changed as frequently as necessary. By removing dust and other abrasive material from the oil, the filter undoubtedly reduces engine wear.

The big disadvantage of the oil filter is that it gives a false sense of security since there are certain contaminants which can only be removed by draining the crankcase oil. To give a few examples:

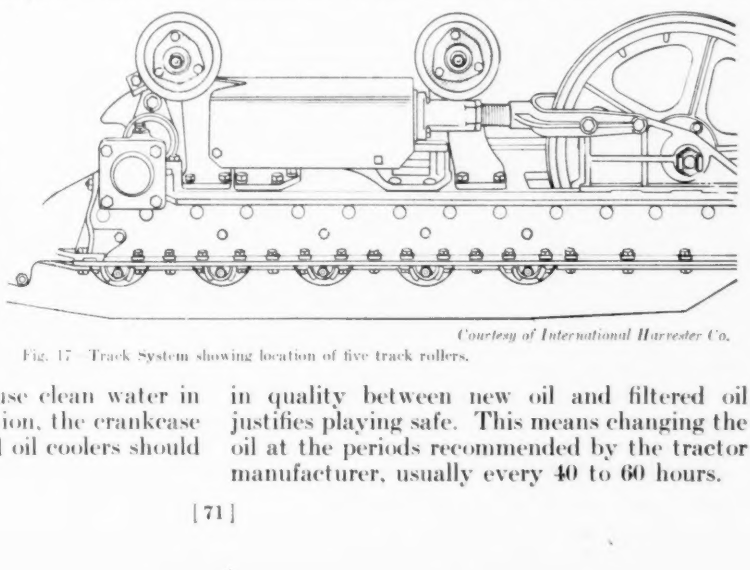
The oil filter cannot possibly remove the large quantities of water-oil emulsions which form when the engine is operated under conditions causing the formation of this type of sludge. As a rule, most of this sludge never reaches the oil filter but collects on the walls of the crankcase, at the oil pump screen and in the oil lines, and can only be removed by a thorough flushing.

Oil may oxidize and form soluble corrosive products, or, under certain operating conditions, sulfur from the fuel forms corrosive acids in the crankcase, which filters do not remove.

Filters also do not remove fuel dilution. This dilution lowers the viscosity of the oil and, in some cases, greatly increases consumption.

There is some evidence that new oils have a greater solvent action on ring deposits than used oils which have been filtered. This is due to the fact that the filtered oils are saturated with oil decomposition products.

For these several reasons, the decision as to when to change the oil depends, not on whether an oil filter is installed but, almost entirely on the engine operating conditions. After all, good lubrication is cheap insurance against high maintenance costs, and the probable difference in quality between new oil and filtered oil justifies playing safe. This means changing the oil at the periods recommended by the tractor manufacturer, usually every 40 to 60 hours.



Courtesy of International Harvester Co.

Fig. 17—Track System showing location of five track rollers.

ENGINE ACCESSORIES

Light engine oils are recommended for gasoline starting engines to insure immediate lubrication of all moving parts.

Air cleaners of the oil-wash type, wherein the air passes through the oil, should be drained daily and refilled with a light straight mineral oil.

Injection pump housings are usually filled with crankcase oil, extra caution being exercised to prevent entrance of dust. Any rise in oil level is the result of fuel leakage passing the pump plungers and, consequently, this point should be checked frequently to detect pump wear.

Magnetos, and generators are best lubricated with a high quality, light machine oil, although for convenience, light motor oils may be used. Electrical equipment suffers more from over-lubrication than from lack of oil. Such parts should be oiled sparingly; otherwise, brushes and other contacts will get dirty.

If water pump requires grease lubrication, a waterproof grease should be used which will not melt below 212 degrees Fahr.

TRANSMISSION

The Diesel tractor transmission is similar to that of heavy-duty trucks, being a system of reduction gears permitting utilization of full engine power at different tractor speeds.

These straight-cut spur gears are best lubricated with straight mineral oils for which they are designed. The gear teeth action and loading are such that compounded or extreme pressure lubricants are unnecessary and undesirable. Straight mineral oils are least apt to thicken or become corrosive in service.

Care must be taken in choosing oil of the proper viscosity or SAE Number* for the particular design and operating temperatures. The viscosity should be high enough to prevent wear, clashing and leakage and yet the oil must be light enough to flow freely under starting temperatures and to permit easy shifting. Viscosity also influences the tendency of the oil to churn or foam.

FINAL DRIVE

From the transmission, power is transmitted at right angles by straight-cut pinion and bevel gears through steering clutches, or differentials to the sprocket driving the track system, or to the tractor wheels through further reduction gears.

Recognizing the advantages derived from the use of straight mineral oils, manufacturers have provided ample tooth area and made frames sufficiently sturdy and rigid to prevent the high-gear tooth pressures, which would necessitate extreme pressure lubricants. Ingenious methods have also been adopted to effectively seal the final drive cases so that soap-thickened oils are unnecessary.

All principal tractor manufacturers warn against the use of any lubricant containing fillers or other ingredients which may cause corrosion of copper parts, high-friction losses, thickening in service, or which might react with water or decompose at high temperatures. To avoid these many difficulties, the same straight mineral oil used in the transmission is recommended for the final drive.

It will be noted that, wherever possible, all parts of the tractor are designed to be lubricated with either the crankcase oil, the transmission lubricant or a light grease. By limiting the number of different lubricants required, the danger of getting the wrong oil in the right place is avoided.

TRACK SYSTEM

In the crawler-type tractor, power is delivered to the track system by a large sprocket wheel. The track is carried around this sprocket in the rear of the tractor and around an idler of similar diameter in the front. The weight of the tractor is supported by several track rollers located on the underside of the track frame.

Although one tractor is equipped with roller bearings in the track rollers, they are normally fitted with two bronze bearings which rotate on a steel shaft. The lubricant is carried in a large space between the bearings. The ends of the bearings are sealed but a sufficient amount of lubricant is allowed to escape to carry away dust, dirt and water. The track roller lubricant serves, not only to furnish an oil film for the bearings but, also, by its flow, prevents the entrance of dirt. The body or viscosity of the track roller lubricant is of the greatest importance since this characteristic governs leakage. The viscosity should be such that the flow is sufficient to keep out dirt, but not enough to endanger running dry between applications of lubricant.

At normal temperatures, either the crankcase oil or the transmission lubricant should be used but, at higher temperatures, heavier, more viscous lubricants are required. Worn track rollers require either heavier lubricants or more frequent application, but the lubricant must never be so viscous that it will not flow freely at starting temperatures; otherwise, rapid wear will result.

* Refer "Lubrication" Volume XXIV, page 51, for SAE Classification.

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